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OVULE FORMATION AS A FACTOR INFLUENCING SEED-SETTING OF LADINO WHITE CLOVER[1]

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Insect pollination is widely known as an essential requirement to seed production in white clover. Darwin (3) and Erith (5) and several others showed that plants protected from insects produced practically no seeds. Self-incompatibility and cross-incompatibility among some related plants, as reported by Williams (6), were later genetically interpreted by Atwood (1) according to the diploid personate type of multiple oppositional allelomorphs. Differences among plants in the average number of seeds set were reported by Atwood (1, 2) and Dessureaux (4). A cytological examination of pistils from representative plants, both before fertilization and during embryo development, indicated that the principal factor influencing the difference in seed-set was the number of ovules born by different plants in the greenhouse (1, 2).

The present investigations were conducted to determine the extent of variation in the number of ovules of Ladino white clover, and to ascertain whether the number of ovules is related to the number of seeds set under open-pollinated conditions in the field. Variability within clonal lines and within flower heads was also investigated in relation to the number of ovules, the number of seeds and the percentage of seed-bearing florets.

MATERIALS AND METHODS

The plant material used throughout these investigations was grown in the individual plant nursery of Ladino white clover. These plants had been transplanted to the field in the spring of 1949 and spaced 3 feet apart, on Ste-Rosalie clay. A number of clonal lines, used in the determination of the number of ovules, were also grown in pots in the greenhouse.

The sampling of the material used to determine the number of ovules per floret was made during the summer, in both the field and the greenhouse, when the plant material was in full bloom. Whenever possible 4 flower heads were sampled at random from each plant. Each sample used to determine the number of ovules per floret consisted of 10 florets taken from the middle section of each head. The mean number of ovules was therefore established from a total of 40 florets for each individual plant or clonal line, unless otherwise specified.

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Ovule counts were made by the use of a stereoscopic binocular, after the ovary had been dissected from the calyx and corolla. The ovules were taken out by first making an opening at the end of the carpel, and then by applying slight pressure with a dissecting needle. The ovules were counted as they emerged from the carpel.

Seed-setting determinations were based on a random sample of 4 heads from each plant. Mature heads were harvested by hand in late September. Whole heads were threshed individually. In the case of open-pollinated progenies and crosses, the number of florets was first determined, and seeds were counted after all the florets had been threshed by rubbing inside a piece of rubber tubing. Then the number of seeds per floret was calculated by dividing the number of seeds by the number of florets. In all other cases, the individual florets were threshed separately and the number of seeds per floret was averaged, thus permitting the establishment of the percentage of seed-bearing florets for each head.

All seed-setting determinations were made on material grown in the field. Nothing was allowed to interfere with bee pollination. The farm apiary was located within one mile of the Ladino white clover nursery.

EXPERIMENTAL RESULTS

Distribution of the Number of Ovules per Floret

A total of 9279 florets were examined in 1949. They were sampled from a number of clonal lines and from various progenies. Most of the material was grown in the field. The distribution of these florets in relation to the number of ovules is shown in Table 1.

The number of ovules per floret was found to vary from 0 to 8. Nearly half of the florets contained 4 ovules. About 95 per cent of the florets contained either 4, 5 or 6 ovules. The frequency of occurrence of 7 or 8 ovules in a carpel was relatively low and apparently restricted to the lower part of the flower head. Similarly, florets with 0, 1, 2 and 3 ovules were few. According to Erith (5), there are from 3 to 7 ovules in the ovary. In a very few plants no ovules were found; this fact seemed to be associated to some extent with an hypertrophy of the carpel. Several hypertrophied virescent carpels were observed to give rise to vegetative growth. These carpels sometimes contained a few ovules on which some kind of appendage was growing. Similar teratological observations were previously reported by Erith (5).

TABLE 1.—FREQUENCY DISTRIBUTION OF THE NUMBER OF OVULES PER FLORET IN A RANDOM SAMPLE OF LADINO WHITE CLOVER

Ovules per floret:									Number of florets
0	1	2	3	4	5	6	7	8	
19	29	75	284	4429	2424	1959	55	5	9279
0.2%	0.3%	0.8%	3.1%	47.7%	26.1%	21.1%	0.6%	0.1%	100%

Mean: 4.6 ovules

Standard deviation: 0.94

TABLE 2.—VARIATION IN THE NUMBER OF OVULES PER FLORET WITHIN FIVE CLONAL LINES OF LADINO CLOVER IN 1949

Plant No.	Clon 1	Clon 2	Clon 3	Clon 4	Mean
46- 662	4.2	4.1	4.2	4.4	4.3
46- 675	5.9	6.0	6.0	6.0	6.0
47- 218	4.6	4.8	4.8	5.0	4.8
48-3638	4.6	4.3	4.7	4.4	4.5
48-3738	5.4	6.0	5.9	5.5	5.7

TABLE 3.—VARIATION IN THE NUMBER OF SEEDS PER FLORET WITHIN FIVE CLONAL LINES OF LADINO CLOVER IN 1949

Plant No.	Clon 1	Clon 2	Clon 3	Clon 4	Mean
46- 662	2.4	2.6	2.0	2.2	2.2
46- 675	3.0	2.5	2.8	2.1	2.6
47- 179	3.3	2.9	3.0	3.3	3.1
47- 218	2.2	2.0	2.1	2.0	2.1
48-3738	2.1	1.8	1.6	3.0	2.1

Variation Within Clonal Lines

The purpose of this experiment was to investigate the extent of variation within clonal lines in relation to the number of ovules, the number of seeds and the percentage of seed-bearing florets. Five clonal lines grown in the field were used for this study. Each clonal line was represented by 4 individual plants.

The mean number of ovules per floret is recorded in Table 2. The analysis of variance indicated that differences between clonal lines were highly significant. However, variation within clonal lines was relatively low and far from significant, as expected from material genetically alike.

The mean number of seeds per floret is reported in Table 3. Differences between clonal lines were highly significant. The difference within clonal lines was statistically significant in 1 of the 5 comparisons. However, the variation in the mean number of seeds per floret among plants vegetatively propagated was generally due to chance alone, with the exception of clonal line 48-3738, in which one individual plant yielded significantly more seeds than any of the three others.

The percentage of seed-bearing florets is given in Table 4. Differences between clonal lines were highly significant. The variance within clonal lines was only 1.7 times smaller than the variance between clonal lines, indicating that the variation within clonal lines was relatively large. However, differences within clonal lines were not generally significant with the exception of clonal line 48-3738. One plant of this clonal line gave a significantly higher value than any of the three others. Since all individuals of a clonal line are genetically alike, some environmental factors are assumed to be responsible for a more complete pollination, which increased at the same time the number of seeds. Environmental changes influencing the efficiency of insect pollination appear to be the main cause of the non-hereditary variation sometimes found in the seed-setting ability of white clover.

TABLE 4.—VARIATION IN THE PERCENTAGE OF SEED-BEARING FLORETS WITHIN FIVE CLONAL LINES OF LADINO CLOVER IN 1949

Plant No.	Clon 1	Clon 2	Clon 3	Clon 4	Mean
46- 662	96.6	95.6	86.8	90.9	92.5
46- 675	96.7	95.0	98.4	87.3	94.4
47- 179	99.2	95.8	94.4	96.7	96.5
47- 218	89.8	90.5	91.9	89.6	90.4
48-3738	85.9	89.8	71.8	98.6	86.5

TABLE 5.—COMPARISON BETWEEN THE MEAN NUMBER OF OVULES, THE MEAN NUMBER OF SEEDS PER FLORET AND THE PERCENTAGE OF SEED-BEARING FLORETS IN FOUR CLONAL LINES OF LADINO CLOVER

Clonal lines	Ovules per floret	Seeds per floret	Per cent of seed-bearing florets
46- 675	6.0	2.6	94.4
48-3738	5.7	2.1	86.5
47- 218	4.8	2.1	90.4
46- 662	4.3	2.2	92.5
Mean	5.2	2.3	91.0

The number of ovules and seeds per floret and the percentage of seed-bearing florets are summarized in Table 5. Clonal line 46-675 had the highest number of ovules and yielded more seeds than the other clonal lines. However, clonal line 48-3738, which also had a high number of ovules, yielded relatively few seeds. The low percentage of seed-bearing florets in the latter may account to a certain extent for the fact that a large number of ovules did not develop into seeds. On the other hand clonal line 46-662, with the lowest number of ovules, produced as many seeds per floret as clonal line 48-3738. These results indicate that the number of ovules and the degree of efficiency in pollination may be equally important factors controlling seed-setting.

Variation Within the Flower Head

The purpose of the following experiment was to investigate the extent of variation within flower heads in relation to the number of ovules, the number of seeds and the percentage of seed-bearing florets. Four clonal lines, grown in the field in 1949, were used in this experiment. The number of ovules was determined at 4 different positions of the head by sampling 10 florets at each horizontal level. The number of seeds was determined at 2 different positions only, by sampling the 10 uppermost and the 10 lowest florets. In 1950, the whole heads of 4 different clonal lines grown in the greenhouse were used to determine the average number of ovules for each group of 10 florets from the base to the apex.

In general the number of ovules within the flower head varies with the position of the floret. Florets located at the base of the head contained more ovules than those at the apex, as shown in Tables 6 and 7. The average number of ovules within heads from a group of 4 clonal lines, listed in Table 7, was respectively 5.1, 4.8, 4.5 and 4.3, according to their

TABLE 6.—AVERAGE NUMBER OF OVULES IN GROUP OF TEN FLORETS LOCATED PROGRESSIVELY FROM BASE TO APEX IN FOUR CLONAL LINES OF LADINO CLOVER GROWN IN THE GREENHOUSE IN 1950

Position of group of ten florets	Clonal lines:			
	47-53	48-1846	47-218	49-1885
Base	4.5	4.2	5.9	5.9
	4.2	4.1	5.8	5.7
	4.1	4.1	5.7	5.6
	4.2	4.0	5.5	5.6
	4.2	4.0	5.4	5.4
	4.3	4.0	5.2	5.1
	4.1	4.0	5.2	5.1
	4.0	4.0	4.9	4.8
	—	4.0	5.2	4.2
	—	—	5.0	—
	—	—	5.1	—
	—	—	4.9	—
	—	—	4.6	—
Apex	—	—	4.4	—

location from the base upward. These differences were highly significant. The gradual decrease in the number of ovules from the base to the apex varied with clonal lines. Clonal lines containing a low number of ovules showed little or no decrease from one location to another on the same head. With the exception of the lowest 10 florets of clonal line 47-53, which contained significantly more ovules than the remaining florets of the head, the number of ovules in all florets was rather uniform for both clonal lines 47-53 and 48-1846. On the other hand, the number of ovules, in clonal lines provided with a relatively large number of them, gradually decreased from the base to the apex. A difference of 1.7 ovules was found between the two extreme positions of the flower head for clonal line 49-1885, as shown in Table 6.

Similarly, florets located at the base of the flower head set significantly more seeds than those at the apex as shown in Table 7. The percentage of seed-bearing florets was also higher at the base. In the lowest florets 57 per cent of the ovules developed into seeds, whereas only 33 per cent of the ovules formed seeds in the uppermost florets. Thus, it appears that the lowest florets are more effectively pollinated than the uppermost ones, presumably because they are more attractive to pollinating insects. It was observed that the percentage of ovules developing into seeds was very low for clonal line 47-53; that may be the result of poor attractiveness, because the percentage of seed-bearing florets was also relatively low.

Variation Between Clonal Lines

The mean number of ovules per floret was determined for a large number of clonal lines, grown both in the field and in the greenhouse in 1949. In general the number of ovules was approximately the same, whether the material had been grown in the field or in the greenhouse. However, a comparison between the coefficients of variability indicated that the variation within clonal lines was greater on the material grown in the field than on that grown in the greenhouse. That can be explained by

TABLE 7.—NUMBER OF OVULES AND SEEDS PER FLORET, AND PERCENTAGE OF SEED-BEARING FLORETS AT TWO DIFFERENT POSITIONS OF THE FLOWER HEAD IN FOUR CLONAL LINES OF LADINO CLOVER IN 1949

Clonal lines	Number of ovules	Number of seeds	Per cent of seed-bearing florets
	Lowest florets		
48-1640	6.0	5.2	100.0
47- 218	5.5	2.5	97.5
48-3737	4.2	2.5	97.5
47- 53	4.6	1.4	72.5
Mean	5.1	2.9	91.9
	Uppermost florets		
48-1640	4.9	1.7	92.5
47- 218	4.1	1.4	75.0
48-3737	4.1	2.1	80.0
47- 53	4.0	0.6	47.5
Mean	4.3	1.4	73.8

difficulties encountered in the sampling technique. Sampling 10 florets in the middle of a flower head is easily done in an insect-proof greenhouse, since all the florets may be in bloom for a short period. In the field, however, florets blooming progressively from the base to the apex are soon pollinated. Consequently, it is sometimes difficult to collect flower heads with blooming florets located at the desired position. The sampling of florets on heads from plants growing in the field was, therefore, more or less at random; that may account for the great variability of the results, and is in agreement with finding that the number of ovules varies with the position at which the florets are sampled.

The mean number of ovules per floret among 70 clonal lines varied from 2.4 to 6.1, with an average of 4.7. Differences between clonal lines were highly significant. These 70 clonal lines represent a random sample of an unselected population of Ladino white clover, and indicate the possibility of selecting Ladino clover plants containing a high number of ovules per floret.

A total number of 63 clonal lines were used to establish the coefficient of correlation between the number of ovules and the number of seeds. A highly significant correlation of 0.415 was found in this case. In general, clonal lines with a high number of ovules tend to yield a high number of seeds, whereas clonal lines with a low number of ovules tend to yield a low number of seeds. On the average only 50 per cent of the ovules developed into seeds. This proportion, however, varies with the clonal lines. It was as high as 80 per cent for some clonal lines and as low as 12 per cent for others. The percentage of seed-bearing florets varied accordingly. Pollination appears to be more effective in some clonal lines than in others, due to the fact that more florets and more ovules were pollinated among the former, thus resulting in high seed sets independently of the relative number of ovules.

TABLE 8.—NUMBER OF OVULES AND SEEDS PER FLORET IN FOUR OPEN-POLLINATED STRAINS OF LADINO CLOVER IN COMPARISON WITH A COMMERCIAL SEED LOT, IN 1949

Strains	Number of ovules	Number of seeds
48-1620	5.0	3.1
48-1600	4.9	3.2
Commercial Ladino	4.5	2.4
48-1357	4.4	1.8
47- 240	4.0	1.4

Variation Among Progenies

The mean number of ovules and seeds per floret was determined in 4 open-pollinated strains, 3 crosses and 1 commercial seed lot of Ladino clover, by sampling 10 individual plants in each progeny. The 4 open-pollinated strains had been developed by maternal line selection for high and low seed-setting. The 3 crosses were made among plants selected for high seed-setting performance.

The mean number of ovules and seeds per floret for the open-pollinated strains is shown in Table 8. The two strains 48-1600 and 48-1620, selected for high seed-setting, had the highest number of ovules and yielded the most seeds per floret. The 2 strains, 47-240 and 48-1357, selected for low seed-setting, produced the lowest number of ovules and seeds per floret. The commercial seed lot of Ladino clover was intermediate between the 2 groups of strains. Differences among open-pollinated strains were highly significant. The differences between individual plants within strains were also highly significant. The inter-plant variance of open-pollinated strains did not differ greatly from that of the commercial seed lot, indicating that maternal line selection for seed-setting did not, in the early generations, reduce the genetic variability of both the number of ovules and the number of seeds per floret. However, the same method of breeding was effective in changing the number of ovules and seeds per floret in both directions.

The mean number of ovules and seeds per floret among crosses is given in Table 9. Differences among crosses were highly significant. The differences between individual plants within each cross were also highly significant. The inter-plant variation was greatly reduced by intercrossing, especially in the case of ovule number. Offsprings from crosses were less variable than offsprings from maternal line selections. Controlled crosses among plants of white clover phenotypically alike lead toward homozygosity.

TABLE 9.—NUMBER OF OVULES AND SEEDS PER FLORET IN THREE FIRST GENERATION CROSSES OF LADINO CLOVER GROWN IN 1949

Crosses	Number of plants	Number of ovules	Number of seeds
47-30 × 47-142	10	4.7	2.9
47-30 × 47- 79	10	4.3	2.7
47-79 × 47-142	10	4.2	2.5

The best seed-producing strains or crosses were, in general, the ones containing the most ovules. High seed-setting plants also tend to have a high number of ovules, but such is not always the case, because the ratio of seeds to ovules varies greatly. It is interesting to note in Table 8 that among the 2 highest seed-setting strains about 63 per cent of the ovules developed into seeds, whereas only 35 per cent to 40 per cent of the ovules formed seeds in the lowest seed-setting strains. The ratio of seeds to ovules among crosses was also relatively high. Selection for high seed-setting, not only sometimes increased the number of ovules per floret, but also resulted in the development of strains more attractive to pollinators. Attractiveness is, partly at least, a logical interpretation for efficiency in the degree of pollination. Reduction in seed-setting may also be brought about by abortion of the seed after fertilization has occurred. It was not determined in these investigations whether the unproductive ovules were due to failure in pollination, fertilization or seed development.

DISCUSSION

Sampling seems to be an important problem in investigating the number of ovules per floret in Ladino white clover. Sampling of flower heads can be made on any individual plant within clonal lines, because the number of ovules does not vary significantly among individuals of a clonal line. Since all members of a clonal line possess an identical germ plasm, they are not expected to vary unless under the influence of environmental factors. From the evidence gathered in the course of the present investigations, the number of ovules per floret does not appear to be influenced by certain conditions of the environment. The number of seeds per floret, however, is a character depending largely on environmental factors, since insect pollination is an essential intervention.

It would be too laborious to use all florets of a flower head. From a practical standpoint it is, therefore, necessary to resort to the sampling of a given number of florets within each head. The differences observed in the number of ovules and seeds among florets depend upon their position on the head, thus indicating the necessity of taking this factor into consideration in the sampling technique. As a first possibility, a random sample of 10 florets could be used to estimate the number of ovules or seeds of an entire head. A good estimate may thus be obtained with the tendency to increase the error variance. A random sampling of 10 florets over an entire head can be easily done for seed counts and for ovule counts in the greenhouse. But this technique cannot be used for material growing in the field, unless screened from insects, as florets are generally pollinated soon after they bloom, thus restricting the number of florets available for random sampling in the case of ovule counts. A second possible technique is to sample a given number of florets on a definite position on the flower head. The middle section of the head appears to be the most desirable position for sampling. The number of ovules or seeds would be over-estimated or under-estimated if florets are sampled from the base or from the apex of the flower head.

The gradual decrease in the number of ovules, seeds and in the percentage of seed-bearing florets from the base to the uppermost florets is assumed to be the result of physiological factors. Morphologically the

flower head of white clover is formed progressively starting from the base upwards, and the first florets to bloom are those located at the base. Competition for nutrients may explain the discrepancy observed between the lowest and uppermost florets. In the lowest florets all or practically all the ovules have the opportunity to develop, because of the direct availability of nutrients. As the florets continue to be formed higher up on the head, competition for nutrients becomes greater with the result that an increasing number of ovules fail to develop in their early stages of growth. In plants genetically provided with a higher number of ovules, the competition for nutrients is more acute than in plants with a low number of ovules, thus explaining why a large discrepancy is observed in the number of ovules formed in the lowest and uppermost florets of plants which have a potentially high number of ovules. Competition for nutrients not only affects the formation of ovules, but seems to be involved in seed development and in the percentage of seed-bearing florets. At the apex of the flower head, where competition is great, the number of seed-bearing florets and the proportion of ovules forming seeds is relatively low. It may be assumed that the reduction in the amount of nutrients also decreased the degree of attractiveness of the uppermost florets. The low number of ovules and the lessened degree of attractiveness were responsible in lowering the seed-setting ability of the uppermost florets as compared with the lowest ones.

The variation among individual plants, clonal lines and strains of Ladino white clover for both the number of ovules and the number of seeds per floret indicates that possibilities of selecting desirable materials for high seed productivity are great. The relationship between these two characters does not imply that selection in one character only would necessarily involve a similar change in the other character, because the efficiency of pollination is perhaps a major factor controlling seed-setting. It is true that a high number of ovules increases the chances for higher seed sets. However, plants with a high number of ovules may give a high or medium number of seeds depending upon the effectiveness of pollination. For the same reason plants which give high seed sets may have a high or relatively low number of ovules. Selection based on seed-setting alone often resulted in an increase in the ovule number, and most generally in a better degree of pollination. Breeding for a higher number of ovules, a higher percentage of seed-bearing florets and specially a higher proportion of ovules forming into seeds appears to be a sound means of developing high seed-setting strains of Ladino white clover.

SUMMARY

The number of ovules and seeds and the percentage of seed-bearing florets were determined for a number of clonal lines and strains of Ladino clover in view of investigating the relationship between these characters.

The number of ovules may vary from 0 to 8. Sets of 4, 5 or 6 ovules in a carpel occurred most often.

The number of ovules per floret did not vary within clonal lines. However, the number of seeds and the percentage of seed-bearing florets were found to vary significantly within one among 5 clonal lines.

Florets at the base of the flower heads generally contained more ovules, yielded more seeds and a higher percentage of seed-bearing florets than the florets located at higher positions. Ovules, seeds and the percentage of seed-bearing florets decreased gradually as the florets grew farther from the base.

The mean number of ovules per floret among 70 clonal lines varied from 2.4 to 6.1 with an average of 4.7. Differences between clonal lines were highly significant for all three characters. The number of ovules and seeds also differed significantly among 4 open-pollinated strains and 3 crosses.

The number of seeds was proportionally related to the number of ovules, provided the degree of pollination was the same. A high number of ovules and a high degree of pollination appear to be the main factors favouring high seed-setting. Selection for high seed-setting only sometimes increased the number of ovules and most generally resulted in a greater efficiency in the degree of pollination. The number of ovules and efficiency in the degree of pollination should be taken into account in a breeding program for seed production in Ladino white clover.

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SOIL PERMEABILITY AS A FACTOR IN THE TRANSLOCATION OF SALTS ON IRRIGATED LAND[1]

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The transportation and accumulation of alkali salts on irrigated lands is the most serious problem confronting irrigation agriculture in the West. Magistad and Christiansen (6) have estimated that on the 20 million acres of land irrigated west of the Mississippi in the United States, crop yields are reduced by 10 to 20 per cent by salinity. There are indications that the situation may become equally serious in Canada. The movement of salts in the soil is controlled by the soil hydraulic properties. The application of hydraulic principles will assist greatly in predicting the probable occurrence of alkali accumulation. Certain recognizable soil and topographical features are conducive to salt accumulation at specific locations.

SALT ACCUMULATION

Salt accumulation on the soil surface and in the root zone is the result of capillary flow of water upward from a saline shallow ground water zone.

Salt deposition and concentration of the soil solution occur when this water evaporates, or is transpired by plants to the atmosphere. The saline nature of this ground water may be due to the dissolution of salts from lower soil zones. However, it has been stated by Magistad and Christiansen (6) that in most cases salts are dissolved and transported in the course of ground water flow from higher lands to lower areas, and deposited at points where conditions for discharge to the soil surface are favourable. The source of this ground water may be influent seepage from canals, irrigation, or natural precipitation.

The abnormal quantity of canal and irrigation seepage water wasted, favours the development of water table profiles* much closer to the soil surface than under natural conditions. When the water table rises within a few feet of the ground surface, the rate of capillary flow upwards becomes considerable. The work of Moore (8) demonstrated that, for a water table depth of 105 cm. (about $3\frac{1}{2}$ feet), the depth of water transported to the soil surface was 0.03 cm. (about 0.012 inches) per day for a fine sandy loam. When the water table was at a depth of 46 cm. ($1\frac{1}{2}$ feet), the rate of water transportation to the surface was 0.46 cm. (0.18 inches) per day. It is pertinent, therefore, to examine the conditions of, and influences on ground water flow which favour the development of dangerously high water tables.

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* The definition of Meinzer (7) for water table profile is "the line along which a given vertical plane intersects the water table". The water table is further defined as the upper surface of the zone of saturation except where that surface is formed by an impermeable body.

HYDRAULICS OF GROUND WATER

Darcy's Law

The fundamental principle governing the flow of ground water may be expressed by Darcy's (3) law. It specifies the relationship between ground water velocity, soil permeability, and hydraulic gradient. Analytically, it may be stated as $v = ki$ where:

v = velocity of flow (L/T)
k = permeability* (L^3/L^2T)
i = hydraulic gradient (no dimension).

Application of Darcy's law for quantitative evaluation of ground water flow may be made in the form $Q = kiA$, which is a derivation of the basic hydraulic formula $Q = vA$ where:

Q = rate of flow (L^3/T)
A = area through which flow occurs (L^2).

It is obvious from the foregoing analysis that water table slopes are developed in direct proportion to the velocity of seepage flow and in inverse proportion to the permeability.

Development of Water Table Profiles

Although flow occurs at all points within the ground water zone, the water table profile development takes place above a horizontal plane passing through the lowest level of discharge. Above this point, the water table slopes are developed in accordance with Darcy's law. This is schematically illustrated in Figures 1 and 2 for the following conditions:

1. Uniform permeability and surface slope.
   (*a*) Natural precipitation vs. natural and canal seepage only.
   (*b*) Natural and canal seepage vs. natural, canal, and irrigation seepage.
2. Constant rate of canal seepage with abrupt decrease of permeability in direction of flow.
   (*a*) Uniform surface slope.
   (*b*) Decreasing surface slope in direction of ground water flow (alluvial cone formation).

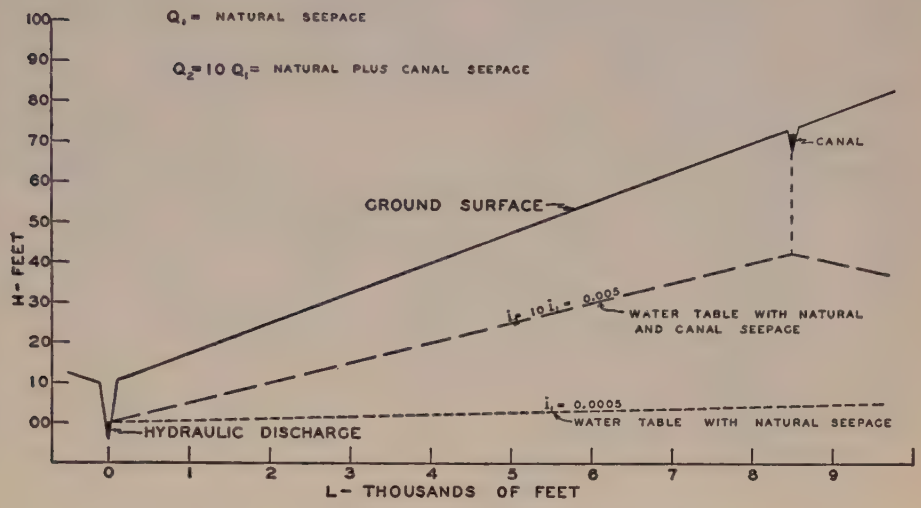
Certain simplifying assumptions are made for the purposes of these illustrations. They are:

1. Steady flow.
2. Single hydraulic discharge level.
3. No evaporative or vegetal discharge.
4. Constant flow cross-section.
5. Uniform flow for single seepage source.

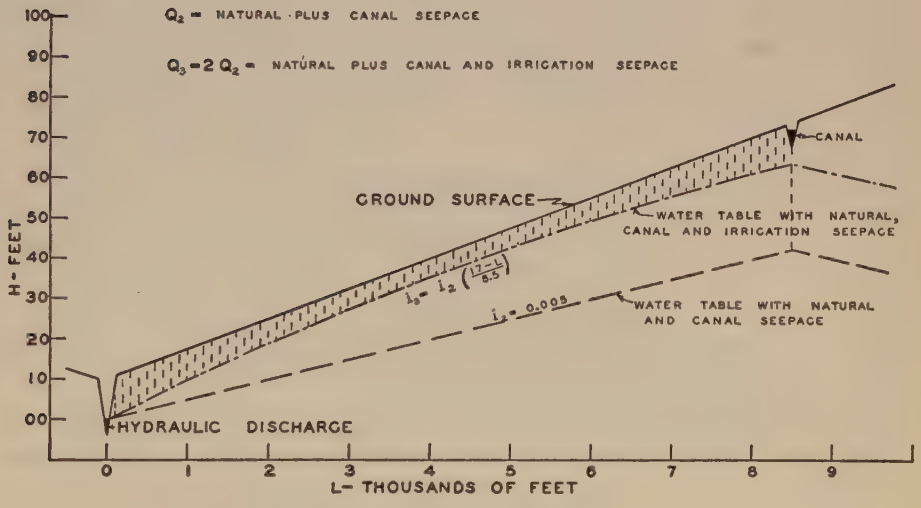
It may be deduced from these illustrations that the following factors, or any combination of factors, operate to produce abnormally high water tables:

1. Excessive canal and/or irrigation seepage.
2. Decreasing permeability in direction of flow.
3. Decreasing surface slope in direction of flow.

* The permeability definition of Muskat (10) is used in this paper.

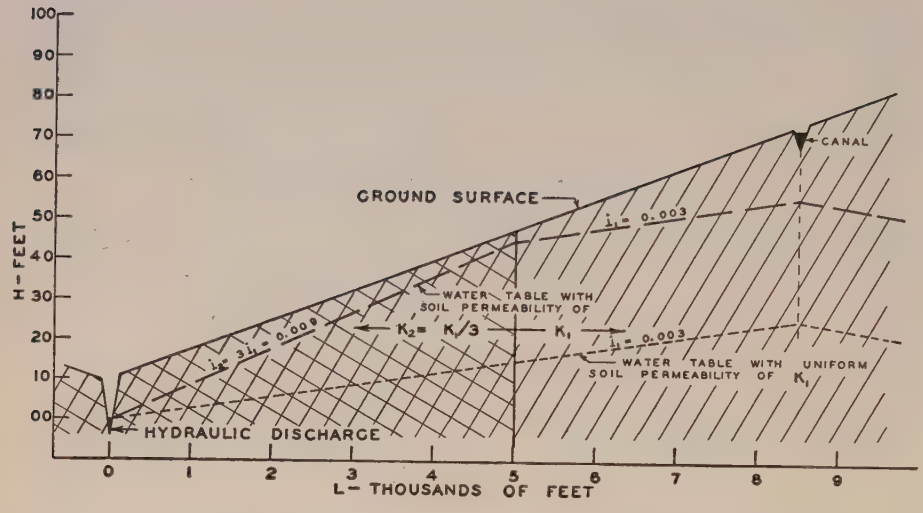


A. PROFILES FOR NATURAL AND CANAL SEEPAGE CONDITIONS

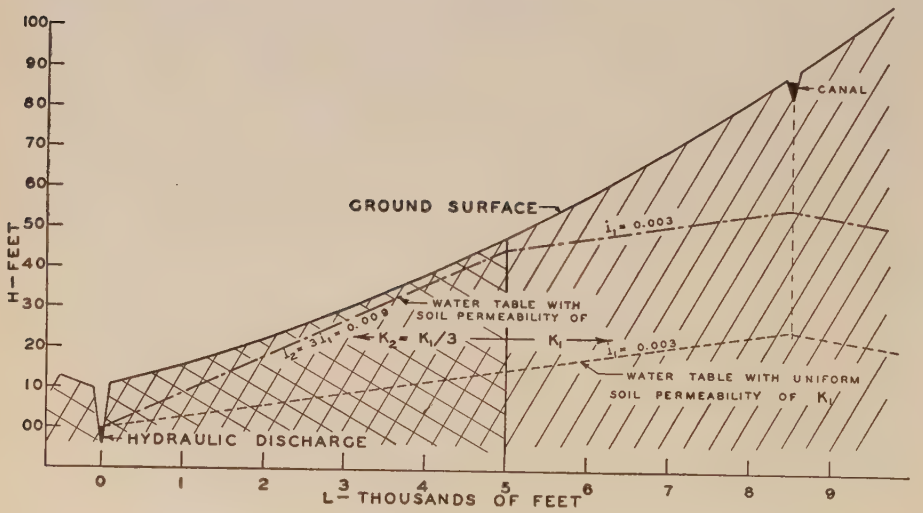

Q_2 = NATURAL PLUS CANAL SEEPAGE
Q_3=2 Q_2 = NATURAL PLUS CANAL AND IRRIGATION SEEPAGE
CANAL
GROUND SURFACE
WATER TABLE WITH NATURAL, CANAL AND IRRIGATION SEEPAGE
$i_3 = i_2\left(\frac{17-L}{8.5}\right)$
i_2 = 0.005
WATER TABLE WITH NATURAL AND CANAL SEEPAGE
HYDRAULIC DISCHARGE
H- FEET
L- THOUSANDS OF FEET

B. PROFILES FOR CANAL AND IRRIGATION SEEPAGE CONDITIONS

FIGURE 1. Water Table Profile Development for Uniform Soil Permeability.



A. UNIFORM SURFACE SLOPE



B. DECREASING SURFACE SLOPE

FIGURE 2. Water Table Profile Development for Soil Permeability Decrease in Direction of Ground Water Flow.

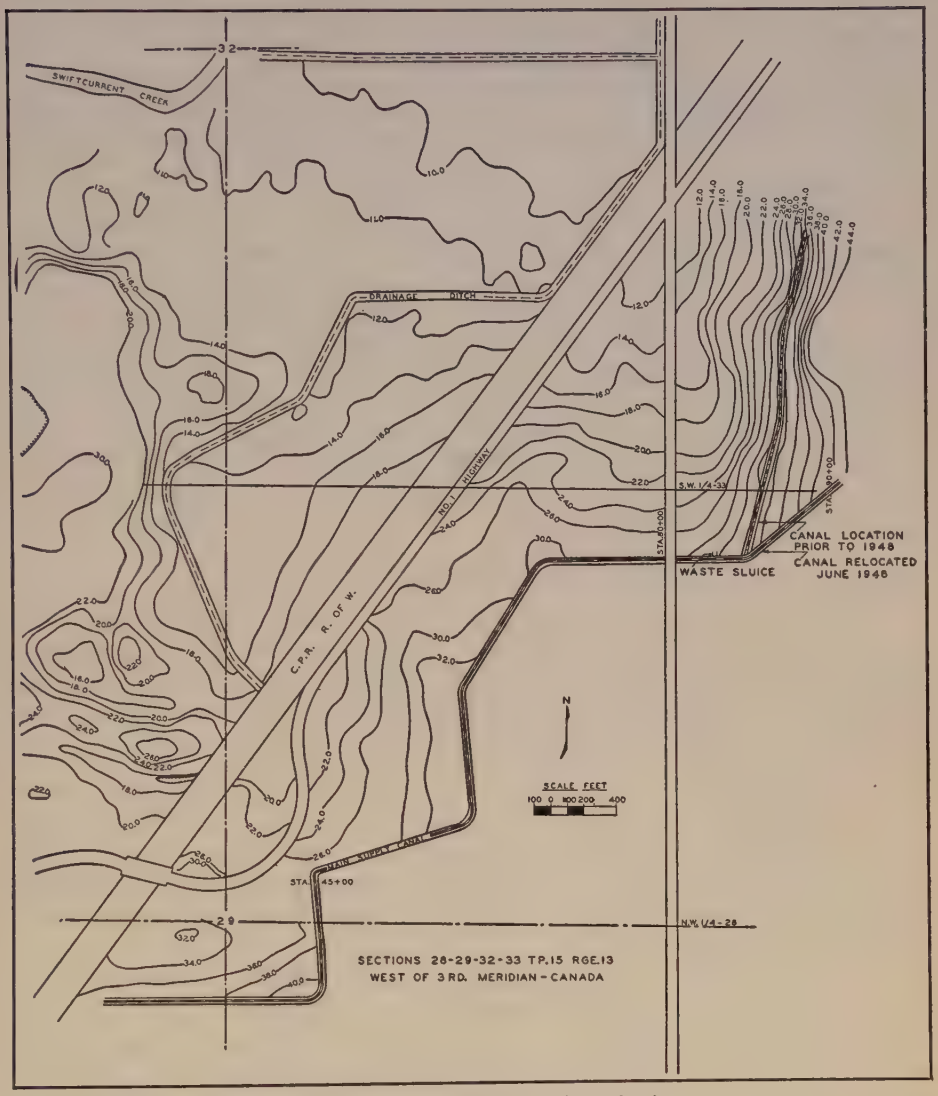


FIGURE 3. Topographical Map of Study Area.

The latter two conditions combined are typical of alluvial formations, and the resultant proximity of the water table to the ground surface over a large area is amply demonstrated in Figure 2B. It may be further inferred from Figure 2A that a heavy salt concentration may occur in a localized region where there is a sharp change in permeability, with a possible decrease in salt accumulation further down the slope. Although the foregoing have been idealized examples, there has been considerable evidence gathered in investigations on the irrigated portion of the Experimental Station of Swift Current to substantiate this reasoning.

GENERAL DESCRIPTION OF STUDY AREA

Topography

For the purpose of this paper, the study area will be confined to the NE. $\frac{1}{4}$ sec. 29, and the SE. $\frac{1}{4}$ sec. 32, tp. 15, rge. 13, W. 3rd mer. As indicated in Figure 3, the topography is nearly level to gently undulating.

Geology and Soils

The area is characterized by a flood plain of recent alluvial deposits bordering the Swiftcurrent Creek. Glacial outwash material occurs along the lower slopes of the valley. Further, to quote from Moss (9):

> "In addition to the glacial and recent deposits, outcrops of Cretaceous shales (Bearpaw Formation) occur along the creek. These shales have probably contributed to the development of the heavier soils of the creek flat. Overlying beds of Tertiary age (Swift Current Formation) also occur on the plateau south of the creek and may have contributed to the development of the light textured soils found in the lowland.
>
> "The various geological deposits mentioned above, and the influence of erosion and deposition of these materials by the creek and its tributaries, have given rise to soils of mixed textures..... In other cases, the deposits are too recent to have permitted full profile development, and the soil consists of medium to light textured soils, while on the creek flat moderately heavy to heavy types predominate".

METHOD OF INVESTIGATION

Ground Water

Since 1946, a study has been under way on the ground water flow characteristics of the area. By the use of auger holes and piezometers (2, 4, 11), the direction of ground water flow and water table profile development was evaluated. In addition, sources of influent seepage were determined. A report of these investigations is contained in an unpublished thesis (1) by this author.

Soil Investigations

In 1949, a stratum soil survey was carried out over the area on an approximate 500-foot grid. Textural classification was made in the field to a depth of about nine feet. Representative soil samples were gathered for salinity appraisal.

The salt content of the profiles was approximated by means of the electrical conductivity method (12), using a 1 : 1 soil water extract.

A limited number of field permeability determinations were made on soils "in situ" below the water table at selected locations. The method used was that of Luthin and Kirkham (5) using one-inch piezometers. Determinations were made in quadruplicate at several depths at each location. This information was further augmented by the textural classification. Texture was used to classify the permeabilities in a relative manner as follows:

1. High permeability—gravel to fine sandy loam.
2. Medium permeability—very fine sandy loam to silty clay loam.
3. Low permeability—silty clay to very heavy clay.

RESULTS AND DISCUSSION

The ground water flow characteristics of the area are indicated on the water table contour map of Figure 4. The displacement of the contours between September 7, 1946, and October 11, 1946, during which time water

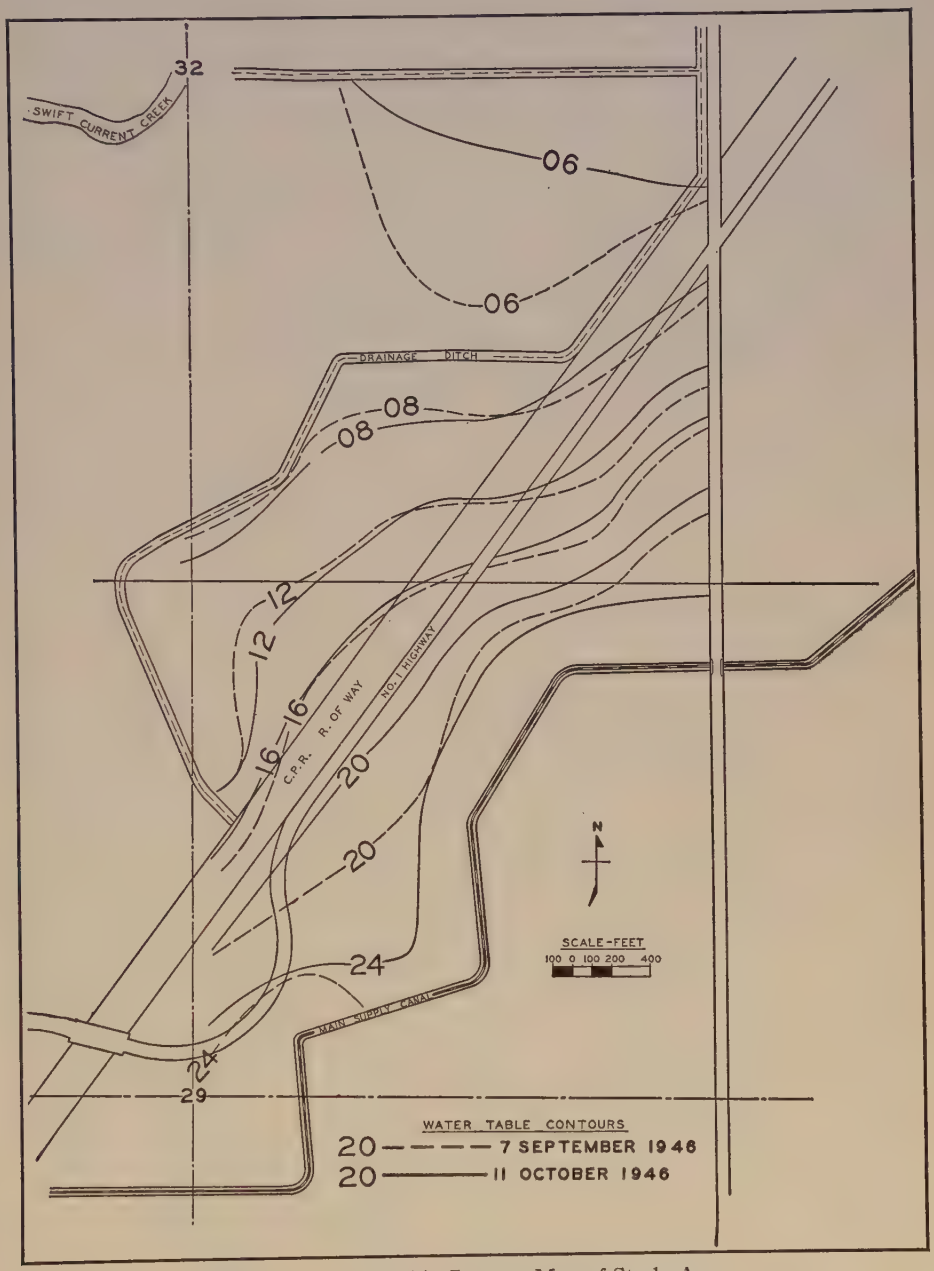


FIGURE 4. Water Table Contour Map of Study Area.

TABLE 1.—SALINITY ANALYSIS

Mean EC × 10^3 mhos./cm.* of 1 : 1 soil-water extract for upper four feet of soil

East-West lines	North-South lines						
	F	E	D	C	B	A	X
025	—	—	—	1.29	—	—	—
020	—	—	—	1.37	1.23	—	—
015	—	—	—	1.16	1.58	—	**8.27**
014 + 50	—	—	—	—	—	1.78	—
010	—	—	**13.86**	**4.95**	**8.55**	**10.12**	3.09
05	—	**9.12**	1.72	0.51	2.67	**4.25**	0.61
0	3.37	**6.76**	**6.35**	0.59	2.83	1.08	0.71
3 + 49	—	—	—	—	—	2.10	—
3 + 92	—	—	—	—	0.64	—	—
5	1.54	**14.56**	1.02	0.58	—	—	—
10	**12.90**	1.21	1.17	0.64	—	—	—
15	**8.80**	1.74	1.14	—	—	—	—
20	2.20	0.82	0.78	—	—	—	—
25	2.70	3.96	—	—	—	—	—
30	0.72	1.26	—	—	—	—	—

* To convert to percentage salts (approx.) multiply conductivity value by 0.07.

TABLE 2.—FIELD PERMEABILITY TESTS BELOW THE WATER TABLE

(Inches per hour)

Location	Test number	Sample depth (in.)	Water table depth (in.)	Soil texture	Mean permeability ± standard deviation (in./hr.)
KP 3	9	34 – 38	29	HvC – SiC	0.26 ± 0.30*
	10	46 – 50	31	SiC	5.80 ± 1.91
	11	82 – 86	33	HvC	1.88 ± 1.08
	12	94 – 98	34	HvC	1.01 ± 0.26
KP 4	13	58 – 62	55	LS	28.8 ± 13.9
KP 5	15	46 – 50	36	HvC – vHvC	0.22 ± 0.04
	16	58 – 62	37	HvC – vHvC	0.56 ± 0.19
	17	70 – 74	38	HvC	2.20 ± 1.41
	18	82 – 86	38	HvC	1.13 ± 0.37
KP 6	19	34 – 38	32	SiC	3.20 ± 2.96
	20	46 – 50	31	SiC	11.78 ± 3.53
	21	58 – 62	34	VFCL	13.13 ± 10.65
	22	70 – 74	35	SiC	10.19 ± 6.84
	23	82 – 86	34	SiC	2.91 ± 0.87
	24	94 – 98	36	SiC with VFCL varve	8.06 ± 4.10
KP 7	25	58 – 62	55	vHvC	0.009 ± 0.005
	26	70 – 74	55	vHvC	0.088 ± 0.015

* The standard deviation in excess of the mean value is probably due to a great actual variation in permeability within the test area.

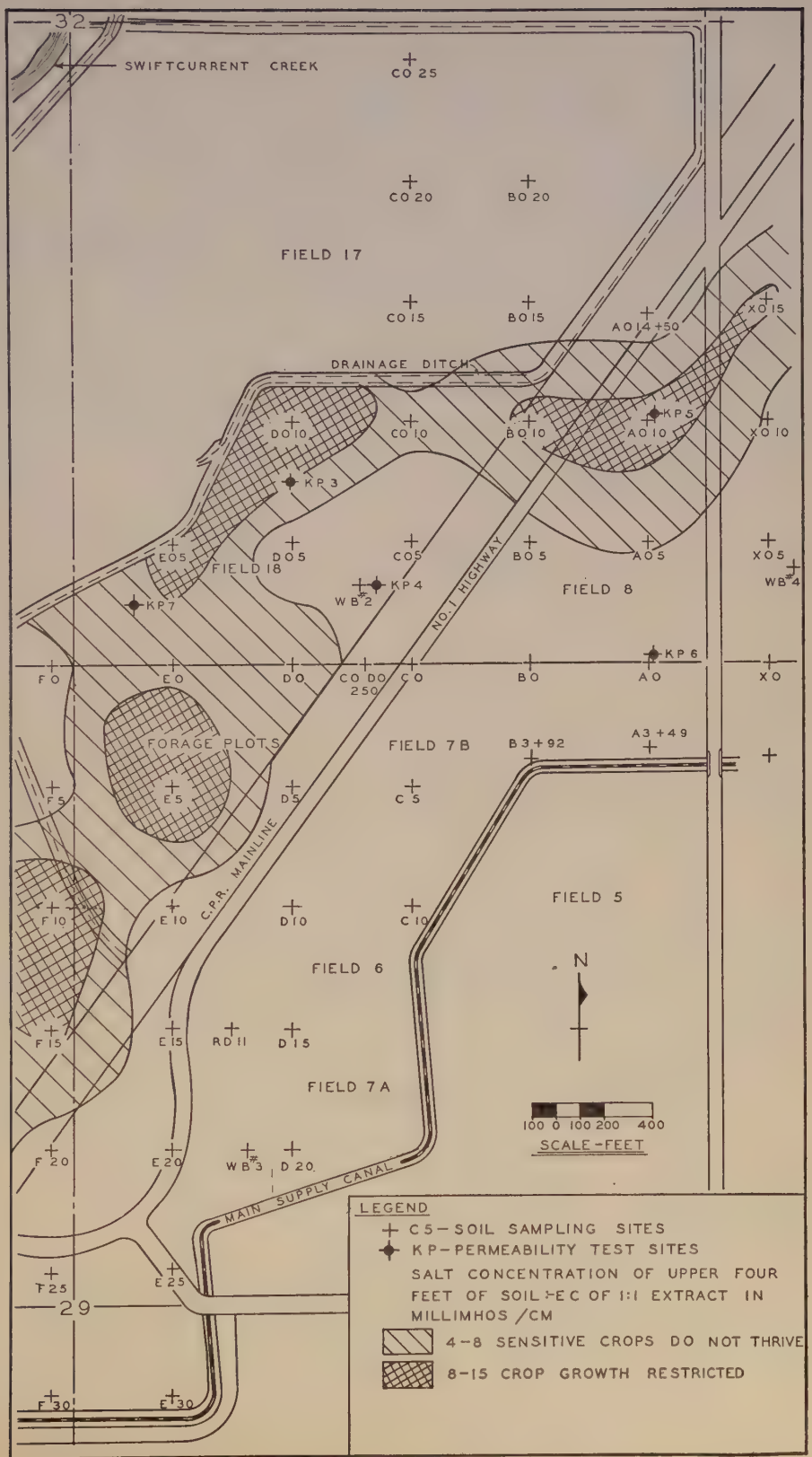


FIGURE 5. Map of Salt Concentrations, with soil sampling and permeability test sites.

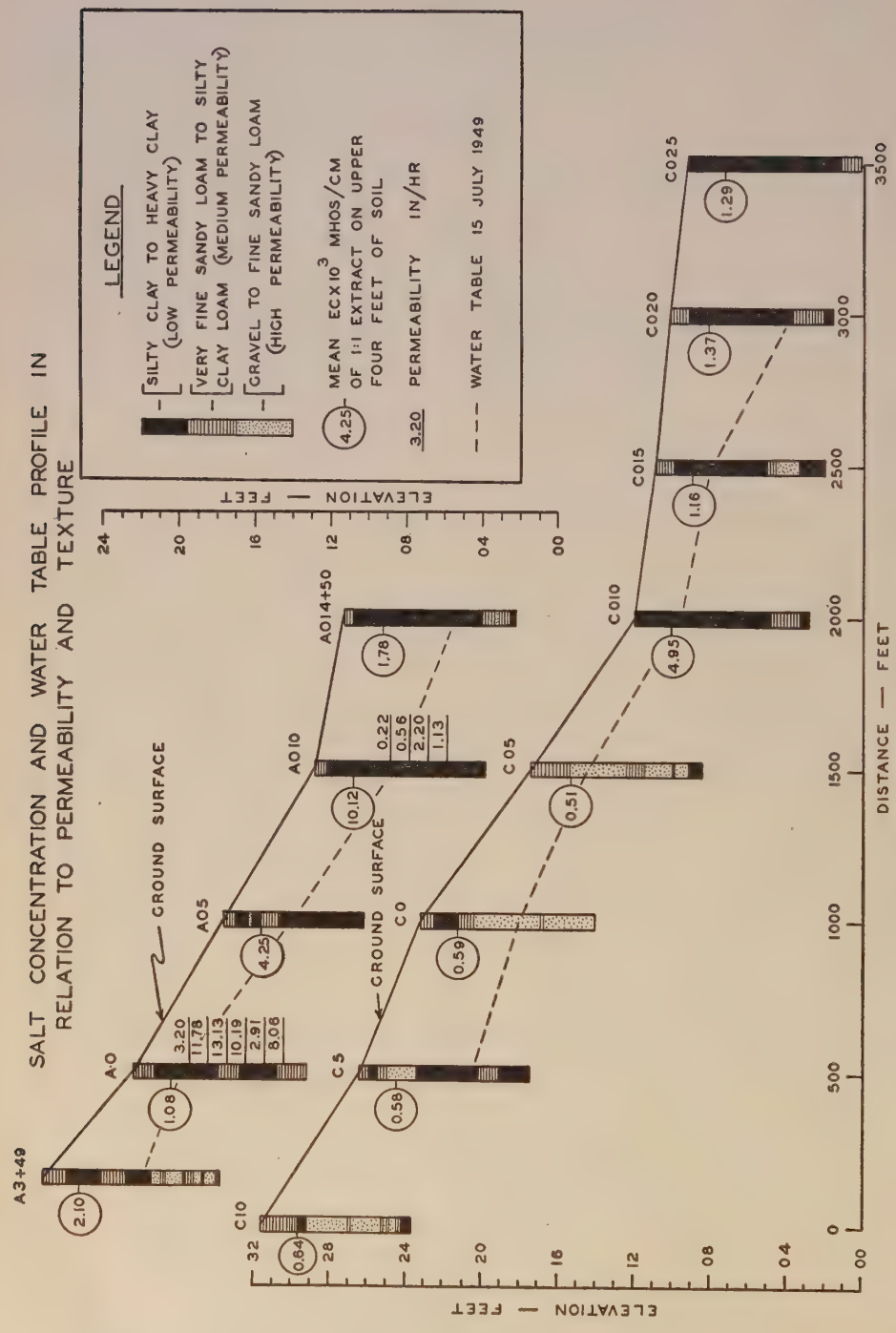


FIGURE 6. Relation of Relative Permeabilities to Salt Concentrations.

was flowing in the canal, indicates that the Main Supply Canal was the major contributor of influent seepage. Before September 7, the canal had been dry for a considerable period.

The results of the salinity survey are summarized in Table 1. Although conductivity determinations were made on most profiles to a nine-foot depth, the average conductivity of the upper four feet, only, is here reported, as this is the zone of principal root activity. These results are illustrated in Figure 5. Only those areas where the conductivity of the extract was in excess of 4 millimhos per centimeter are delineated. This is the arbitrary lower limit for conductivity of the saturation extract at which sensitive crops do not thrive as set by the United States Regional Salinity Laboratory (12). Had saturated extracts been used in these determinations, the conductivities would have been higher and the areal extent of the adversely affected area somewhat greater. The area of salt concentration forms a continuous band of varying width, paralleling the Main Supply Canal in the same manner as the water table contours. The salt concentration in the areas, both above and below this band, are much lower.

Typical sets of soil profiles in the direction of ground water flow are illustrated in Figures 6 and 7. In every case, the salt concentrations occur where the soil profiles change from predominantly coarse or medium textures to fine textures. Actual permeability values for the ground water zone are indicated on profiles A0 and A010 of Figure 6. The mean permeability of profile A0 is approximately eight times that of A010. The ratio of salt concentrations in the two profiles is approximately in the same inverse ratio. Further permeability determinations are summarized in Table 2. It is obvious from these and their position relative to the salt concentration (Figure 5) that concentrations are greatest in areas of relatively low soil permeability, and that these areas occur on the flat, lower lying regions. Examination of the ground surface profiles reveals that they are all fairly typical of the alluvial cone.

CONCLUSIONS

It may be concluded from these studies that certain recognizable features of topography and soils should bear special attention in the pre-investigational program connected with the irrigation of valley lands in particular. The feature requiring special attention is the alluvial cone associated with soils of low permeability on the lower areas bounded by soils of higher permeability. Preventive measures that may be undertaken are:

1. Canal lining to prevent excessive seepage.
2. Interception drainage to prevent high water tables in soils of low permeability.

SUMMARY

By an analysis of ground water theory, it was found that high water table profiles may be the result of excessive canal or irrigation influent seepage, decreasing soil permeability in direction of flow, or alluvial cone topographical formation, or a combination of these. It was found from investigations at Swift Current that all such conditions were prevalent.

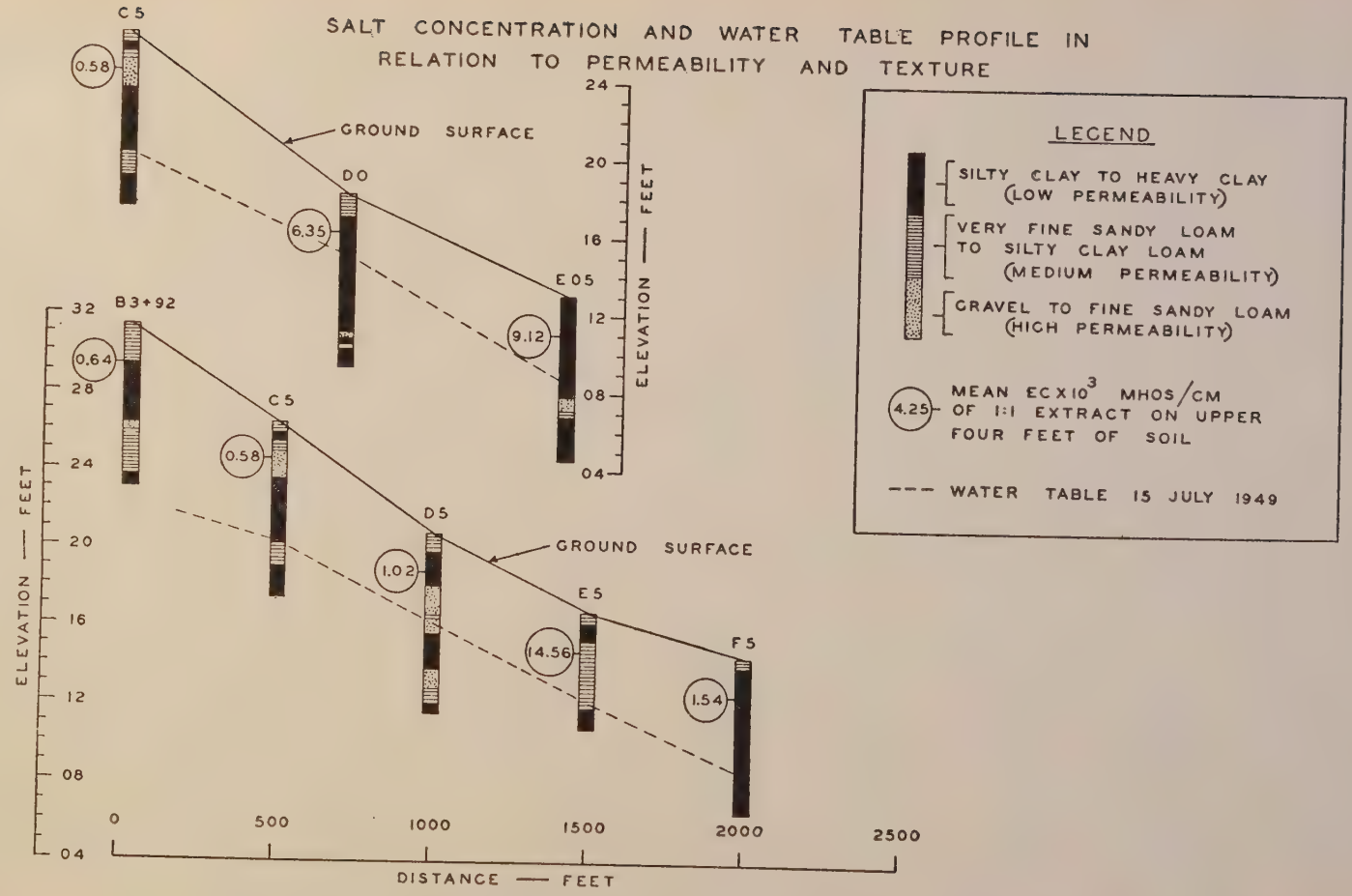


FIGURE 7. Relation of Relative Permeabilities to Salt Concentrations.

The locus of salt concentration occurred in every case where there was a decrease in soil permeability in the direction of ground water flow. Relative permeabilities were indicated both by actual field measurement and by textural classification. A prior knowledge of such conditions would provide a basis for the planning and execution of the preventive measures of canal lining or interception drainage during the construction phase of irrigation development.

ACKNOWLEDGMENTS

The writer wishes to express his appreciation to A. Ballantyne, of the P.F.R.A., for the soil sampling and textural classification, and to Earl More, Experimental Station, Swift Current, and P. C. Chang, P.F.R.A., for assistance in making permeability determinations and salinity analyses. Helpful criticism of the manuscript was received from J. L. Thompson, Experimental Station, Swift Current. Advice and assistance of the Division of Field Husbandry, Soils, and Agricultural Engineering, Central Experimental Farm, Ottawa, Canada, is acknowledged.

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A PRELIMINARY INVESTIGATION OF ORCHARD GRASS SEED PRODUCTION AS INFLUENCED BY NITROGEN APPLIED AS A SPRAY[1]

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[Received for publication February 22, 1951]

The beneficial effect of substantial nitrogen applications on grass seed production has been well established. Substantial increases in yield have been obtained at Ottawa by applying up to 80 lb. of nitrogen per acre. It would appear, however, that at Ottawa and elsewhere the beneficial effects of nitrogen are largely dependent on moisture conditions. It has been pointed out by several workers that the rhizomatous grasses in particular fail to give appreciable response to nitrogen under conditions where soil moisture is limited for a prolonged period after application. In 1949 and again in 1950, a small experiment was established on spaced rows of orchard grass to compare the relative effect of 80 lb. of nitrogen drilled in as a side dressing with that of an equivalent amount sprayed on the foliage. The results obtained are recorded here.

EXPERIMENTAL METHODS AND PROCEDURES

Two nitrogen sources, namely ammonium nitrate and urea, were used. The urea was in the form of the commercial product, "Nu Green", a highly soluble compound which has been reported to be effective as a nitrogen spray in orchards. The material was dissolved in water and the mixture applied at the rate of 100 gallons per acre by the use of hand sprayers. The ammonium nitrate was diluted with sand and drilled in as a side dressing.

Plot size was approximately 1/80 of an acre and was made up of three rows. The centre row, an area of 1/242 of an acre, was harvested for yield determinations. Five treatments replicated six times in a random block arrangement were used. Treatments were as follows:

1. Check.
2. 40 lb. N in form of ammonium nitrate drilled in first week in May.
   40 lb. N in form of ammonium nitrate drilled in 30 days later.
3. 80 lb. N in form of ammonium nitrate drilled in first week of May.
4. 40 lb. N in form of "Nu Green" sprayed on first week of May.
   40 lb. N in form of "Nu Green" sprayed on 30 days later.
5. 80 lb. N in form of "Nu Green" sprayed on first week in May.

The 1950 treatments were applied to the same plots as those which were treated in 1949, and in the same order; thus the 1950 yields may have been influenced by any residual effect that may have prevailed.

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[1] Contribution from the Division of Forage Plants, Experimental Farms Service, Central Experimental Farm, Ottawa, Ont.

[2] Senior Agronomist.

[3] Technical Officer.

EXPERIMENTAL RESULTS

Table 1 gives the seed yield data for the two years of the test.

TABLE 1.—SEED YIELDS FROM PLOTS FERTILIZED WITH NITROGEN (YIELDS CALCULATED IN LB. PER ACRE)

Treatment	Average seed yield = lb. per acre		
	1949	1950	2-Year average
1. Check	216	38	127
2. 80 lb. N-ammonium nitrate (split application)	295	69	182
3. 80 lb. N-ammonium nitrate (single application)	273	52	163
4. 80 lb. N-"Nu Green" (split application)	302	52	177
5. 80 lb. N-"Nu Green" (single application)	255	81	168
L. S. D. (P = 0.05)	79	27	31

The winter of 1949-50 was particularly severe. Strains of orchard grass less hardy than "Hercules", the variety used in this test, suffered severe winter killing. It is believed that the markedly lower seed yields obtained in this test in 1950 were due to injury to the primordial tissue. This was indicated by the great reduction in the number of flowering stalks. Injury was not apparent in the spring of the year although it was observed that spring growth was retarded.

There are contradictions in this data which cannot be readily explained. In 1949, treatments Two and Four gave yields significantly higher than the check, while in 1950 treatments Two and Five were the ones that were significantly higher. Thus the split application of ammonium nitrate was significantly higher in both years, while the split application of "Nu Green" gave the highest yield of the test in 1949 but was not significantly higher than the check in 1950.

When the data are considered on a two-year basis it is found that all treatments are significantly higher than the check while the four treatments may be considered similar in yield. The two "Nu Green" treatments gave an over-all average yield for the two years of 173 lb. per acre, which is identical with that given by the two ammonium nitrate treatments over the same period.

DISCUSSION

Of primary interest in this experiment is the finding that a nitrogen compound which may be absorbed through the plant leaves has given results comparable to that obtained when nitrogen is applied in a solid form. There has been no measure of how the beneficial effect of the sprayed nitrogen was derived. The rapidity with which the vegetation changed colour would seem to justify the conclusion that a considerable portion of

the nitrogen was absorbed by the leaves. On the other hand, consideration must be given to the possibility that substantial amounts of the fertilizing material fell to the ground and was therefore available to the plants only through the roots.

The results obtained from this rather limited test do not justify conclusions as to the practical value of a spray application of nitrogen. It would seem, however, that further investigation of this method, particularly under dryland conditions, would be justified. It is possible that, under conditions of limited moisture, plants would be no more capable of fully utilizing the nitrogen applied to the leaves than they would nitrogen in the solid form.

There may be a further field of investigation in the possibility that a herbicide and nitrogen might be combined in one spray operation, to give weed control and plant stimulation at the same time. In such an approach consideration should be given to establishing the minimum amount of water necessary for dilution, in order to obtain a practical basis of application.

SUMMARY

1. A preliminary investigation was carried out at the Division of Forage Plants, Central Experimental Farm, Ottawa, on the effect on orchard grass seed production of nitrogen applied in the solid form as compared with nitrogen sprayed on the foliage.

2. Nitrogen, in the form of urea, when sprayed on orchard grass foliage at the rate of 80 lb. of nitrogen per acre, gave significant increases in seed yield over the check.

3. The nitrogen fertilization, sprayed on, gave seed yields comparable to those obtained when an equal amount of nitrogen was applied in the solid form.

EFFECT OF SOURCES OF NITROGEN, RATES OF APPLICATION AND METHOD OF APPLICATION ON SEED PRODUCTION OF ORCHARD GRASS[1]

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[Received for publication February 22, 1951]

The increasing demand for seed of the meadow grasses, a demand stimulated by the expanding grassland program in this country, has created interest in grass seed production. While it does not seem likely that acreage yields can be obtained in Ontario that will be comparable to those of more favoured areas, there is reason to expect yields which will be attractive from a cash-crop standpoint.

There are a number of factors which influence grass seed production in Eastern Canada. One of the most important of these is soil fertility. Given soil of high fertility, very abundant seed crops can be obtained. In other areas it has been found that applications of nitrogen can have marked influence on seed yield. The most extensive work on nitrogen fertilization for grass seed production has been undertaken in Europe. Hansen (8) showed that up to 60 kg. pure nitrogen per hectare is followed by increased seed yield of timothy. Wraae-Jensen (7) obtained similar results. In Sweden results indicate that 300 kg. of nitrate of soda per hectare is most suitable. Nilsson-Leissner (12) obtained an increase approximately similar in size with uniform incremental doses of nitrogen up to 400 kg. per hectare. In Norway, Lier (11) found 480 lb. of nitrate of soda per acre the most economic rate on timothy.

With orchard grass results have been generally similar to that obtained with timothy. Andersson (1), Hansen (7) and Nilsson-Leissner (12) obtained substantial increases in seed yield from nitrogen applications. Andersen (2) found no extra benefit from a split fall and spring application as opposed to a single spring application. In the United States, Spencer (14) and Jones *et al.* (10) found that seed yields of orchard grass and tall fescue were markedly increased by substantial applications of nitrogen. Dermanis (4) and Weller (16), reporting on meadow fescue, concluded that half the nitrogen should be applied in the fall and half in the spring.

Evans (5) points out that rhizomatous species and strains do not respond to nitrogen to nearly the same extent as species with a tufted habit of growth. He found that an application of nitrogen to species such as creeping red fescue and Kentucky blue grass may quite often result in a substantial reduction in seed yield. Findings contrary to those of Evans are reported by Spencer *et al.* (15), Anderson *et al.* (3), Harrison and Crawford (9) and North and Odland (13). Spencer and his co-workers found that nitrogen gave marked increases in yield of blue grass, while North and Odland obtained increased yields of colonial bent seed by the use of nitrogen. Anderson and Harrison and Crawford found that smooth brome grass, a species with pronounced rhizomatous habit, responded to nitrogen fertilization. Unpublished data from the Dominion Experimental

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Station, Melfort, Saskatchewan, indicate that increased yield can be obtained by fertilizing smooth brome with nitrogen if moisture conditions are favourable. In dry seasons response to nitrogen was found to be negligible.

Fulkerson *et al.* (6) reported on the effect of nitrogen, phosphate and potash on seed production of seven common grass species. They found that five different nitrogen carriers, applied at the rate of 40 lb. nitrogen per acre, brought about increased seed yields on orchard grass and that some of the carriers decreased the seed yield for the year following the application. Meadow fescue and timothy did not respond to nitrogen fertilization at the 40-lb. rate of application.

The experimental work reported here was designed to ascertain the effect of different nitrogen carriers, applied at different rates and methods, on seed production of orchard grass. Data obtained in the crop years of 1949 and 1950 are presented.

EXPERIMENTAL TREATMENTS AND PROCEDURES

The area chosen for this experiment was a two acre-block of fairly uniform Grenville loam soil, considered to be in a fair state of fertility and in good physical condition. Grenville loam is generally described as a brown or dark loam with a top soil five to seven inches thick. Natural fertility of this soil is considered medium and drainage is excellent. Reaction is neutral to mildly alkaline.

In the spring of 1948 an application of 400 pounds of 0-14-7 fertilizer was applied to this area and worked in. The area was then seeded to "Hercules" orchard grass in two-foot drills. No nurse crop was used. Establishment was good, so that by the spring of 1949 well established rows of orchard grass were available for fertilization.

The test as laid down comprised a total of 300 plots in which there were: (*a*) six rates of nitrogen application; (*b*) two methods of application; (*c*) five nitrogen carriers, and (*d*) five replicates. The plots were arranged in what may be termed a "split-split" latin design in which nitrogen sources were the main plots, rates of application the first sub-plots, and methods of application the second sub-plots.

TABLE 1.—SOURCES, RATES AND METHODS OF NITROGEN APPLICATION

Sources of nitrogen		Rate of elemental N. application		Method of application	
Sy.	Compound	Sy.	Rate	Sy.	
N 1	Ammonium sulphate (20 per cent)	R 1	None	M 1	The total amount of N. applied in one application during the first week of May.
N 2	Sodium nitrate (16.3 per cent)	R 1	20 lb. per acre		
N 3	Ammonium nitrate (33.5 per cent)	R 3	40 lb. per acre		
N 4	Calcium cyanamid (21 per cent)	R 4	80 lb. per acre		
N 5	Urea, "Nu-Green", (43 per cent)	R 5	160 lb. per acre	M 2	Half the amount applied during the first week of May and the remaining half 30 days later.
		R 6	320 lb. per acre		

Each plot consisted of three adjoining single rows, 30 feet long. The centre row was used for yield determinations. Fertilizer, adulterated with sand, was applied as a drilled-in side dressing to both sides of each of the three rows making up each plot.

Determinations for seed yield and other factors were made in a uniform manner so that in all cases the data are comparable. Established seed laboratory technique was followed to convert the seed data to a pure seed basis.

The key shown in Table 1 will facilitate discussion of the data since it shows sources of nitrogen, rates and methods of application.

The above procedures were followed without alteration for the crop years of 1949 and 1950. However, it must be emphasized that the 1950 treatments were superimposed on the same plots that received treatment in 1949, so that the 1950 series was favoured by any residual effect that might prevail from 1949.

EXPERIMENTAL RESULTS

The main interest in this test is the effect of the different levels of nitrogen applied, and of the five nitrogen carriers used, on seed yield and seed weight. However, the effect of the treatments on seed stalk development from the standpoint of both numbers and height, and on seed germination, have also been noted and are reported here.

A. Seed Yield

Yield of seed on a per acre basis, as obtained in 1949, is given in Table 2. It is apparent from this table that differences in yield due to sources of nitrogen and methods of application are not significant. Rates of application show a significant figure at the 5 per cent point, while there is also a significant interraction between methods and sources. When rate one, which is the check, is excluded, the average yield for rates two to six over the five sources, for method One is 269.6 lb. per acre while that for method Two is 270.9 lb. These average figures cover a total of 125 determinations for each method.

A considerable range of variation exists between the yields of the five nitrogen carriers but significance has not been established at the 5 per cent point. When all determinations for rates and methods, excluding the check, are considered, calcium cyanamid has shown the top yield of 292 lb. per acre and ammonium nitrate the lowest yield with 258 lb. Since a significant mean square value was obtained in the interaction of methods $\times$ sources it may be concluded that there may be a differential response between the nitrogen carriers as regards method of application.

When the level of significance established for rates of application is applied to the means of 50 observations covering two methods and five sources it is apparent that rate 4 (80 lb. N), rate 5 (160 lb. N) and rate 6 (320 lb. N) have given yields significantly higher than the check. The 80 lb. N rate gave optimum results, producing a yield of 53 lb. or approximately 22.5 per cent more seed than the check.

The yields obtained in 1950 were less than one-third of those obtained in 1949. This drop in yield is believed to be due to winter injury. The winter of 1949-50 was very severe and orchard grass strains less hardy than

TABLE 2.—SUMMARY OF DATA SHOWING THE EFFECT OF DIFFERENT NITROGEN CARRIERS, APPLIED AT DIFFERENT RATES AND TIMES ON SEED YIELD OF ORCHARD GRASS—YIELDS IN POUNDS PER ACRE 1949

Rates per acre	Method (1) single application					Method (2) split application					Means of 50 observations
	Means of 5 observations										
	N 1	N 2	N 3	N 4	N 5	N 1	N 2	N 3	N 4	N 5	
	Ammonium sulphate	Sodium nitrate	Ammonium nitrate	Calcium cyanamid	"Nu-Green" (urea)	Ammonium sulphate	Sodium nitrate	Ammonium nitrate	Calcium cyanamid	"Nu-Green" (urea)	Means for rates
1. 0 lb.	245.5	217.2	225.3	211.7	240.8	219.5	241.9	230.3	275.5	243.4	235.1
2. 20 lb.	259.4	245.8	259.3	240.8	253.3	253.0	284.9	248.4	320.0	234.2	259.9
3. 40 lb.	292.3	255.9	240.0	269.1	239.9	272.9	232.0	260.7	270.5	247.1	258.0
4. 80 lb.	339.2	293.2	234.1	268.9	282.3	304.9	283.7	301.3	286.8	288.2	288.3
5. 160 lb.	307.1	249.0	250.7	336.8	272.1	242.1	295.9	248.9	323.5	279.4	280.5
6. 320 lb.	263.2	248.1	250.6	297.8	292.0	265.5	247.0	286.3	307.4	290.2	274.5
Average (rates two to six)	292.2	258.4	246.9	282.7	269.6	267.1	268.7	269.1	301.6	267.8	272.2

ANALYSIS OF VARIANCE

Sources	D.F.	M.S.	F value obtained	F value for 5 per cent	Remarks
Main plots—					
Sources of nitrogen	4	9,018.70	—	3.26	No significant difference
Rows	4	239,199.03			
Columns	4	34,303.10			
Error "A"	12	18,275.50			
Sub-plots—					
Rates	5	18,337.65	2.79	2.30	L. S. D. = 34.10 lb.
Rates × Sources N	20	2,872.59			
Error "B"	100	6,573.11			
Sub-sub-plots—					
Methods	1	3,365.41	2.40	3.92	No significant difference
Methods × Sources	4	6,176.11	4.40	2.44	Significant
Methods × Rates	5	971.22			
Methods × Sources × Rates	20	2,015.92			
Error "C"	120	1,405.18			

TABLE 3.—SUMMARY OF DATA SHOWING THE EFFECT OF DIFFERENT NITROGEN CARRIERS, APPLIED AT DIFFERENT RATES AND TIMES ON THE SEED YIELD OF ORCHARD GRASS—YIELDS IN POUNDS PER ACRE 1950

Rates per acre	Method (1) single application					Method (2) split application					Means of 50 observations
	Means of 5 observations										
	N 1	N 2	N 3	N 4	N 5	N 1	N 2	N 3	N 4	N 5	
	Ammonium sulphate	Sodium nitrate	Ammonium nitrate	Calcium cyanamid	"Nu-Green" (urea)	Ammonium sulphate	Sodium nitrate	Ammonium nitrate	Calcium cyanamid	"Nu-Green" (urea)	
R 1 — 0 lb.	46.0	39.6	40.0	46.9	33.0	43.4	53.2	43.5	60.1	37.8	44.4
R 2 — 20 lb.	57.3	57.6	66.4	42.7	65.0	62.6	54.6	73.7	59.0	50.2	58.9
R 3 — 40 lb.	63.8	84.6	74.6	64.5	71.1	66.2	90.6	81.5	70.9	62.7	73.1
R 4 — 80 lb.	93.8	107.0	109.9	70.4	91.4	109.3	102.5	103.1	75.2	78.5	94.1
R 5 — 160 lb.	96.8	140.9	140.2	68.5	92.8	92.4	117.1	134.1	62.5	86.4	103.2
R 6 — 320 lb.	118.5	81.8	123.4	107.2	123.7	104.7	91.5	121.6	110.0	101.7	108.4
Mean yield— Sources (rates two to six)	86.0	94.4	102.9	70.6	88.8	87.0	91.2	102.8	75.5	75.9	—
Mean yield— Methods (rates two to six)	—	—	—	—	88.5	—	—	—	—	86.5	87.5

L. S. D. required for significance at the 5 per cent point, between rates in all sources and methods = 15.2 lb.

the "Hercules" variety, used in this test, were badly winter-killed. While winter injury was not too apparent in the "Hercules" variety after three weeks of spring growth there is a strong possibility that there was considerable injury to primordial tissue. This conclusion can be drawn from the fact that the number of flowering stalks, as indicated in data to follow, were greatly reduced in numbers in 1950.

Analysis of the 1950 data summarized in Table 3 shows that as in 1949 only between rates of application were there significant differences in yields. The yields for the five nitrogen carriers ranged between 70.6 and 102.9 lb. for method One and between 75.5 and 102.8 lb. for method Two. When the yields of the five nitrogen sources for all rates (except rate one), and methods are averaged, it is found the ammonium sulphate gave a yield of 86.5 lb.; sodium nitrate 92.8 lb.; ammonium nitrate 102.9 lb.; calcium cyanamid 73 lb., and "Nu-Green" 82.4 lb. This order did not hold in 1949. Ammonium nitrate, which gave the highest yields in 1950, was lowest in 1949. While, as pointed out previously, no significance can be attached to these differences in yield, it may be concluded that there may be a difference in the efficiency of the various nitrogen carriers under varying soil and climatic conditions.

All rates of nitrogen application gave significantly higher values than the check when yields are considered on the basis of the means of 50 observations made up of five nitrogen carriers and two methods of application. Rates 4, 5 and 6 gave significantly higher yields than rates 2 and 3. Rate 6 exceeded rates 2, 3 and 4. While the yields for 1950 are abnormally low, emphasis may be placed on the fact that the application of 80 lb. nitrogen or more produced yields more than double those of the check.

By combining the data for all sources and all methods it has been possible to consider the effect of the rate of application on a two-year basis. A summarization of these data is as follows:

Rates	*Means* (lb. per acre)
R 1 — 0 lb. N	141
R 2 — 20 lb. N	159
R 3 — 40 lb. N	166
R 4 — 80 lb. N	191
R 5 — 160 lb. N	192
R 6 — 320 lb. N	192
Mean — Rates 2 to 6	180
L. S. D. (P. = 0.05)	21
C in per cent	21

In these data rates 3, 4, 5 and 6 are shown to have produced yields significantly higher than the check and rates 4, 5 and 6 higher than the check and rates 2 and 3. The application of 80 lb. of nitrogen per acre (equivalent to 240 lb. ammonium nitrate) has resulted in yields approximately 35 per cent greater than those of the check. The greater rates of 160 and 320 lb. have not shown greater increases than the 80-lb. rate.

B. Seed Weight

Determinations for seed weight were made on a 1000-seed basis. A pure seed basis was established and due consideration given to the usual occurrence of double florets in orchard grass. Table 4 presents a summary

TABLE 4.—SUMMARY OF DATA SHOWING THE EFFECT OF DIFFERENT NITROGEN CARRIERS, APPLIED AT DIFFERENT RATES AND TIMES ON THE WEIGHT OF ORCHARD GRASS SEED—WEIGHTS IN GRAMS PER 1000 SEEDS—1949

Rates per acre	Method (1) single application					Method (2) split application					Means of 50 observations
	Means of 5 observations										
	N 1	N 2	N 3	N 4	N 5	N 1	N 2	N 3	N 4	N 5	
	Ammonium sulphate	Sodium nitrate	Ammonium nitrate	Calcium cyanamid	"Nu-Green" (urea)	Ammonium sulphate	Sodium nitrate	Ammonium nitrate	Calcium cyanamid	"Nu-Green" (urea)	Means for rates
1. 0 lb.	0.948	0.984	0.934	0.939	0.906	0.905	0.892	0.888	0.893	0.937	0.914
2. 20 lb.	0.895	0.872	0.917	0.917	0.921	0.938	0.897	0.908	0.872	0.922	0.907
3. 40 lb.	0.972	0.910	0.923	0.942	0.937	0.915	0.915	0.914	0.883	0.978	0.929
4. 80 lb.	0.930	0.953	0.955	0.949	0.920	0.958	0.906	0.939	0.919	0.945	0.937
5. 160 lb.	0.964	0.941	0.935	0.930	0.948	0.961	0.893	0.929	0.921	0.857	0.932
6. 320 lb.	0.933	0.958	0.942	0.930	0.956	0.949	0.931	0.951	0.918	0.957	0.943
Average for sources	0.938	0.927	0.934	0.934	0.936	0.944	0.908	0.928	0.903	0.932	0.930
Mean methods— (rates two to six)	—	—	—	—	0.934	—	—	—	—	0.923	—

L. S. D. (P. = 0.05) between rates in all sources and methods = 0.021 grams.
L. S. D. (P. = 0.05) between methods in all sources and rates = 0.0095 grams.

ANALYSIS OF VARIANCE

WEIGHT OF ORCHARD GRASS SEED AS INFLUENCED BY NITROGEN TREATMENTS

Sources	S.S.	D.F.	M.S.	F. value obtained	F value for 5 per cent	Remarks
Main plots—						
Sources of N	0.02984	4	0.00746	1.02	3.26	No significant difference
Rows	0.10666	4	0.02667			
Columns	0.01872	4	0.00468			
Error "A"	0.08751	12	0.00729			
Sub-plots—						
Rates	0.04898	5	0.00979	3.40	2.30	L. S. D. = 0.02127
Rates × Sources	0.02511	20	0.00125			
Error "B"	0.28791	100	0.00288			
Sub-sub-plots—						
Methods	0.00871	1	0.00871	4.98	3.92	= L. S. D. = 0.0095
Methods × Sources	0.01539	4	0.00385	2.20	2.44	No significant difference
Methods × Rates	0.00682	5	0.00136		2.29	
Methods × Sources × Rates	0.09439	20	0.00472			
Error "C"	0.21065	120	0.00175			

TABLE 5.—SUMMARY OF DATA SHOWING THE EFFECT OF DIFFERENT NITROGEN CARRIERS, APPLIED AT DIFFERENT RATES AND TIMES ON THE SEED WEIGHT OF ORCHARD GRASS SEED—WEIGHTS IN GRAMS PER 1000 SEEDS—1950

Rates per acre	Method (1) single application					Method (2) split application					Means of 50 observations
	Means of 5 observations										
	N 1	N 2	N 3	N 4	N 5	N 1	N 2	N 3	N 4	N 5	
	Ammonium sulphate	Sodium nitrate	Ammonium nitrate	Calcium cyanamid	"Nu-Green" (urea)	Ammonium sulphate	Sodium nitrate	Ammonium nitrate	Calcium cyanamid	"Nu-Green" (urea)	Means for rates
R 1 — 0 lb.	1.0845	1.1307	1.0999	1.1005	1.0896	1.0721	1.0869	1.1180	1.1256	1.0621	1.0970
R 2 — 20 lb.	1.1464	1.1472	1.1047	1.1371	1.1027	1.1295	1.1681	1.1482	1.1222	1.0992	1.1305
R 3 — 40 lb.	1.1778	1.2023	1.1623	1.1214	1.1420	1.1704	1.2018	1.1654	1.1510	1.1511	1.1645
R 4 — 80 lb.	1.1520	1.2388	1.1617	1.1824	1.1881	1.1767	1.1693	1.2056	1.1380	1.1831	1.1796
R 5 — 160 lb.	1.2354	1.2251	1.1692	1.2043	1.1845	1.1962	1.1734	1.1513	1.1557	1.1731	1.1868
R 6 — 320 lb.	1.2007	1.1566	1.2085	1.2010	1.1664	1.1935	1.1572	1.1764	1.2475	1.1486	1.1856
Mean yields— Sources (rates two to six)	1.1825	1.1940	1.1613	1.1692	1.1567	1.1733	1.1740	1.1694	1.1629	1.1510	—
Mean yield— Methods (rates two to six)	—	—	—	—	1.1727	—	—	—	—	1.1661	—

L. S. D. (P. = 0.05) between rates in all sources and methods = 0.02601 grams.

of the data obtained in 1949. Analysis of these data reveals that there were significant differences between the yields obtained from the different rates of application and also between those obtained from methods of application. Sodium nitrate and calcium cyanamid gave appreciably higher values under method One than under method Two. Rates 3, 4, 5 and 6 gave significantly higher seed weights than the check and rate 2. On the other hand it would appear that rates in excess of 40 lb. N did appreciably increase seed weight although it is noteworthy that the highest rate of 320 lb. N established the highest seed weight. Table 5, presenting the 1950 data, reveals that rates of application, as in 1949, developed significant values. Rates 3, 4, 5 and 6 gave weights that exceeded those of the check and rate 2 to a significant degree.

The following two-year summary, in which all sources of nitrogen and methods of application are combined, indicates seed weights from rates similar to those mentioned above.

Rates	*Means* (Wt. in gm. per 1000 seeds)
R 1 — 0 lb. N	1.0282 gm.
R 2 — 20 lb. N	1.0283 gm.
R 3 — 40 lb. N	1.0547 gm.
R 4 — 80 lb. N	1.0621 gm.
R 5 — 160 lb. N	1.0682 gm.
R 6 — 320 lb. N	1.0510 gm.
L. S. D. (P. = 0.05)	0.0347
C in per cent	25.2 per cent

C. Flowering Stalks

Observations were made on effect of the various nitrogen treatments on the production of flowering stalks in both 1949 and 1950. Counts were made on each plot in the experiment on a per foot basis. No significant difference was established in either of the two years due to sources, rates or methods. There was, as mentioned previously, a great reduction in the number of flowering stalks in 1950 as compared with 1949. This is indicated by the following two year-summary:

Rates	Mean number of flowering stalks	
	1949	1950
R 1 — 0 lb. N	61	12
R 2 — 20 lb. N	58	13
R 3 — 40 lb. N	61	14
R 4 — 80 lb. N	60	14
R 5 — 160 lb. N	60	15
R 6 — 320 lb. N	57	15

It is of interest to note that a high positive correlation was established between the number of flowering stalks and seed yield.

	r	5 per cent	1 per cent
1949	+ 0.409	0.113	0.148
1950	+ 0.518	0.113	0.148

The heights of the flowering stalks were in such close agreement for both years and throughout all treatments that no significance could be attached to them. This is indicated by the following two-year summation.

Rates	Height of flowering stalks in inches, 1949-1950	
	1949	1950
R 1 — 0 lb. N	42	42
R 2 — 20 lb. N	42	43
R 3 — 40 lb. N	41	44
R 4 — 80 lb. N	41	43
R 5 — 160 lb. N	39	43
R 6 — 320 lb. N	38	43

D. Forage Yield

There were indications in this test in 1949 that high seed yield could be coupled with high dry matter yield. Dry matter determinations therefore were taken in 1950 from the outside rows in each treated plot. When resolved on an acre basis the yields of dry matter were found to follow the same pattern developed for seed yield, namely no significant differences between yields for methods and sources, but a significant value for rates. When this value was applied to the following means for rates it was found that all nitrogen rates gave yields greater than the check while rates 4, 5 and 6 exceeded the check and rates 2 and 3.

Rates	Dry matter yield— Means 50 observations, lb. per acre
R 1 — 0 lb. N	2358
R 2 — 20 lb. N	3045
R 3 — 40 lb. N	3125
R 4 — 80 lb. N	3707
R 5 — 160 lb. N	3767
R 6 — 320 lb. N	4040
L. S. D. (P. = 0.05)	376

A high positive correlation was obtained when dry matter yield was correlated with seed yield. Thus it would appear that in this test flowering stalk and vegetative stimulation by nitrogen was complementary.

	r	5 per cent	1 per cent	n
Dry matter per acre and seed yield per acre	+ 0.550	0.113	0.148	300

DISCUSSION

Under the conditions of this experiment substantial increases in orchard grass seed yield were brought about by nitrogen applications of 80 lb. or more. The data indicate that optimum results were obtained at the 80-lb. rate level. This is in accordance with the findings of other workers. In this test, applications of 160 and 320 lb. of nitrogen did not give improvement over the 80-lb. rate and can therefore be considered as having been excessive.

Significant differential responses from the various types of nitrogen fertilizers have not been established. It is suggested that under more or less extreme conditions, such as high or low moisture, high or low temperature, etc., certain of the nitrogen sources might show up to better advantage. This fact would have to be established by tests of long duration especially in areas where moisture supply and temperature vary widely from year to year. Even then, the information might not be of much value, since at the time of application knowledge of the subsequent climatic conditions would not be available. In areas where low moisture is the rule it would be advisable to investigate the reaction of the various nitrogen fertilizers.

While two methods of application have been under investigation in this experiment and have been found to give similar results, variations of the methods used might influence seed yield. Time of application in both the spring and autumn could show important variations. Similarly, drilled versus broadcast fertilization might show significant differences. These methods and times of application could vary in their beneficial effects from season to season depending on climatic conditions.

While data such as reported here may be applicable in a general way to large areas, it is evident that detailed recommendations for any particular area should be based on experimental work carried on in that area.

SUMMARY

1. In a field experiment conducted over a two-year period at the Central Experimental Farm, Ottawa, the effect of nitrogen fertilization on orchard grass seed production was studied. Five different nitrogen fertilizers were applied to orchard grass vegetation in two ways at five different rates.

2. The form of nitrogen fertilizer was not of importance. Comparable results were obtained from ammonium sulphate, sodium nitrate, ammonium nitrate, calcium cyanamid and urea.

3. Seed yields in orchard grass were increased by approximately 35 per cent by the application of 80 lb. or more of nitrogen per acre.

4. The 80-lb. rate of application was as effective as a rate of 160 or 320 lb.

5. There was no advantage in a split application of nitrogen in the spring over a single application.

6. Weight per 1000 seeds was affected by nitrogen fertilization in a manner similar to that of seed yield.

7. A significant difference in number and height of flowering stalks was not established due to treatment. However, a high positive correlation was obtained between number of flowering stalks and seed yield.

8. Nitrogen fertilization stimulated dry matter yield. There was a high positive correlation between dry matter yield and seed yield.

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ERRATUM

In the paper by J. E. R. Greenshields, entitled "Polyembryony in Alfalfa", published in the May, 1951 (Vol. 31, No. 5) issue, page 214, para. 2, line 4, the word "polyhaploid" should have been printed, instead of "polyploid".

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